MEPAG

Mars Strategic Science Assessment Group

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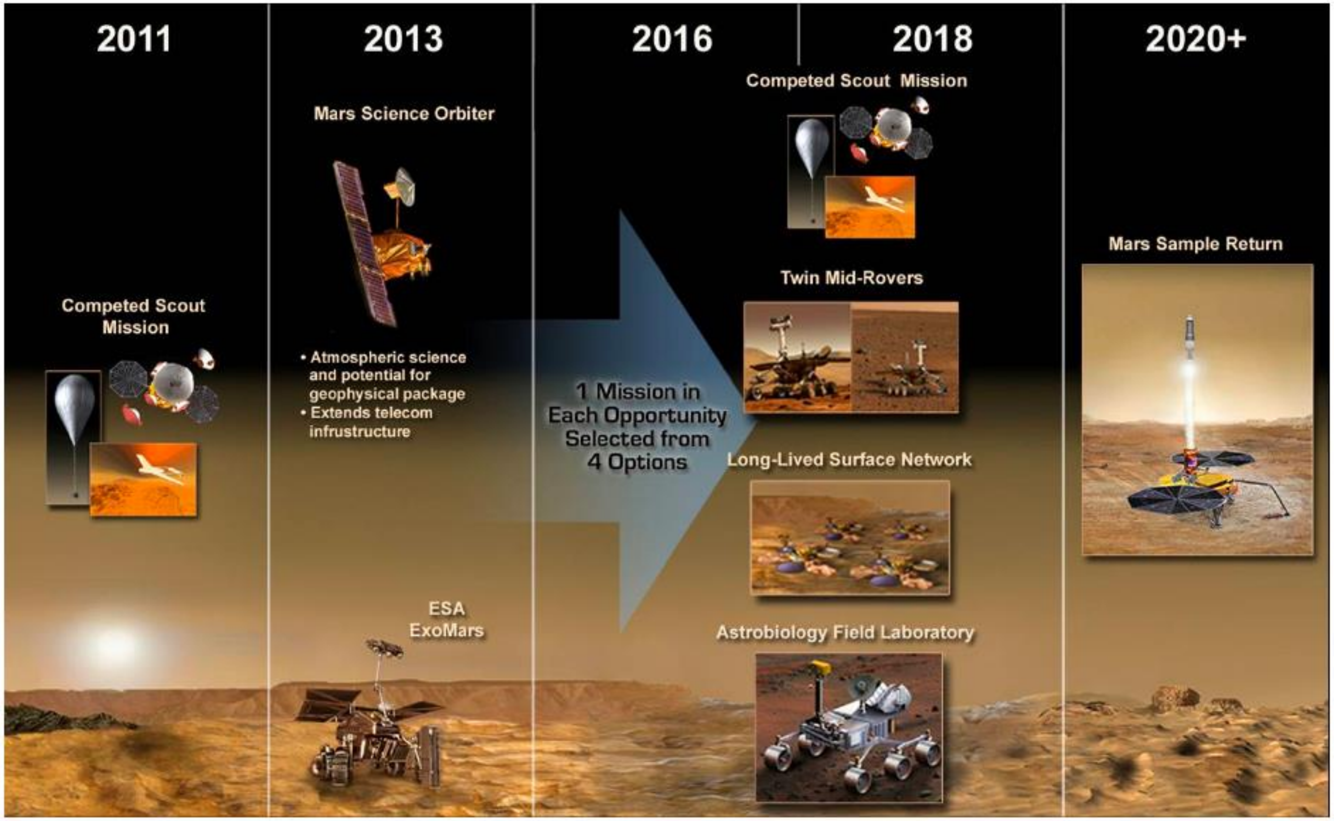
MEPAG Mars Stategic Science Assessment Group

- ❑ **"MSS-SAG"**
- ❑ **Follow-on to ND-SAG charged by MEPAG to answer questions from Alan Stern:**
  - <u>What would be the first and second priorities for strategic missions prior to MSR?</u>
  - <u>What critical Mars science can be accomplished in conjunction with and complementing MSR?</u>
- ❑ **Interdisciplinary membership covers all MEPAG goals**
  - Scott Murchie, JHU/APL (chair, Goal III)
  - Richard Zurek, JPL (co-chair, Goal II, Mars Program Office)
  - Lisa Pratt, Indiana U (Goal I)
  - Wendy Calvin, U Nevada (Goals II, II)
  - Sushil Atreya, U Michigan (Goal II)
  - Michael Smith, GSFC (Goal II)
  - Phil Christensen, ASU (Goal III)
  - Christophe Sotin, JPL (Goal III)
  - Carl Allen, JSC (Goals III, IV)
  - John Mustard, Brown U (ex officio, Goal III, MEPAG chair)

How We Proceeded

- 2-hr weekly telecons, 12/19 through 2/12
- **Topics considered**
  - MSR recommendations by ND-SAG
  - Findings from Mars Express, Mars Odyssey, MER, MRO in 2004-2008
  - Roles of orbital and landed missions in future landing site selection
  - Science objectives and capabilities of three candidate new missions
    - Mars Science Orbiter (atmospheric science)
    - Mars Network (meteorology / geophysics)
    - Mid-range Rover (geology)
  - Possible complementary science on MSR
- **Face-to-face meeting in Pasadena, CA, Jan.. 30-31 to address**
  - Roles of new and existing missions in MSR site selection activities
  - Mission sequence after 2013
  - Complementary science on MSR-Orbiter
  - Complementary science on MSR-Lander
- **Mars Architecture Tiger Team, Herndon, VA, Feb. 14-15**

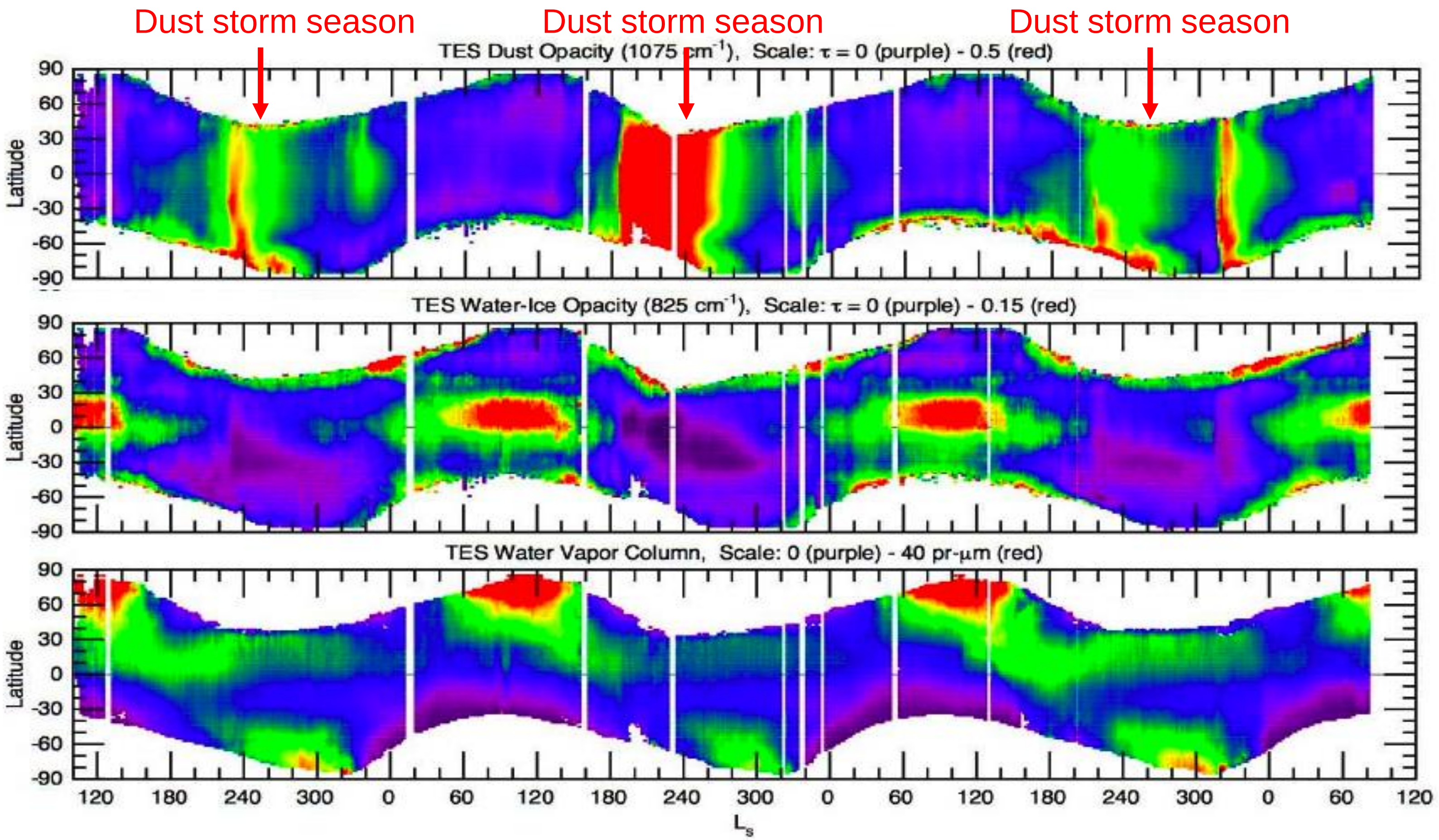
Historical Perspective



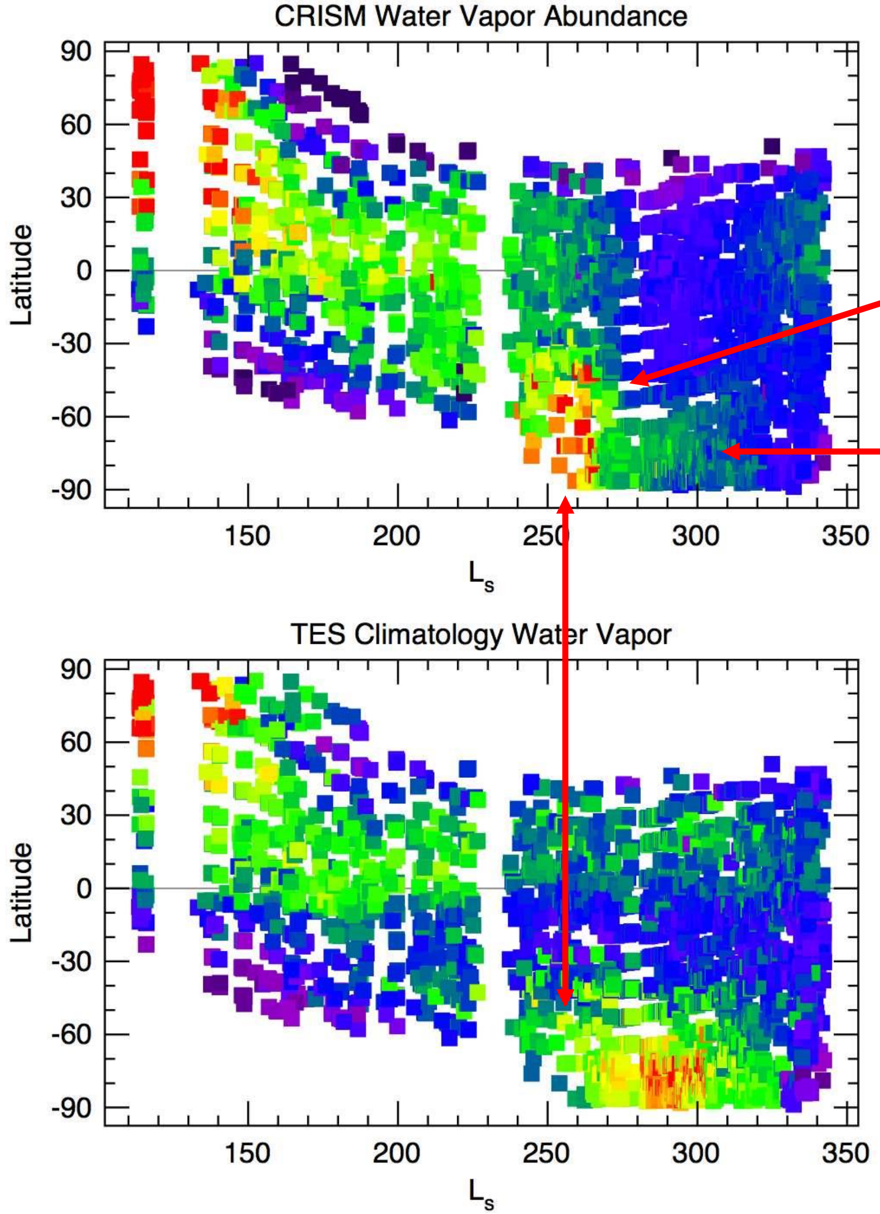
- **This was the view in 2006 of missions to follow MSL**
- **New science results (MRO) were envisioned as a driving force**
- **What has changed?**
  - Scout focused on aeronomy but proposed launch slipped to 2013
  - MSR Lander would not launch any later than 2020.
  - We *HAVE* new results - and lessons learned from how they were obtained.

Lessons from Atmospheric Monitoring

- A long-term observation baseline (MGS, MRO) has been thought vital to understanding climate
- A 3-year baseline from TES indicated little interannual variation except during dust-storm season



MEPAG Lessons from Atmospheric Monitoring



- **Continuing monitoring into 2007 reveals previously unseen variations**
  - **S hemisphere water vapor maximum was earlier and stronger**
  - **(Monitoring during the dust event was problematic)**

Lessons from Atmospheric Monitoring

- **New techniques are revealing new aspects of Mars' atmosphere**
  - Three-dimensional structure is only now being investigated
  - What is the long-term variability?
- **Trace gases (methane, other hydrocarbons, halogen and sulfur species, etc.) are vitally important but are poorly characterized or undetected**

QuickTime™ and a TIFF (LZW) decompressor are needed to see this picture.

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MRO/MCS measurements of water ice and dust abundance vs. height, longitude

Lessons from Orbital Remote Sensing

- **Deposits with both physical and mineralogic evidence for past environments are critical to understanding the history of water near Mars' surface**
  - Bedforms and stratigraphy can indicate the sequence of processes, and constrain what the processes were
  - Aqueous mineralogy confirms the presence of water, and preserves a detailed record of the past environment
  - Clays and precipitates preserve a chemical record of biomarkers
- **TES, THEMIS, OMEGA, and CRISM have followed a strategy of increasing wavelength range and higher spatial resolution**
  - Each has complemented previous investigations by re-imaging aqueous mineral sites, using better wavelength coverage and/or resolution.
  - Each has found previously unrecognized evidence for aqueous minerals.
  - Nearly all of this was since the last strategic mission (MSL) was initiated.
- **At least 8 classes of deposits with distinctive mineralogy, structures, and stratigraphy are recognizable in current data**

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Timeline of Discovery of 8 Classes

Short name	MGS/TES	Mex/OMEGA	Odyssey/ THEMIS	MER	MRO/CRISM MRO/HiRISE
Meridiani-type layered deposits	Deposits of gray hematite	Adjacent occurrences of mono- and polyhydrated sulfates	-	In situ measurements reveal geologic history	Improved resolution of vertical stratification
Valles-type layered deposits	Patches of gray hematite	Adjacent occurrences of mono- and polyhydrated sulfates, gypsum, Fe oxides	-	-	Intricate vertical layering of sulfate types; folding; alteration zones
Gypsum plains	-	Gypsum-rich optical surface	-	-	Role of eolian reworking; relationship to basal unit
Layered phyllosilicates	-	Al- and Fe/Mg-clays at Nili and Mawrth	-	-	Thin interbedding of clay units; detailed stratigraphy
Massive phyllosilicates	-	Unknown hydrated mineral associated with dozens highland craters	-	-	~10K highland outcrops in craters, chasmata; chlorite + other phyllosilicates
Phyllosilicates in fans	-	-	-	-	Highland crater fans/deltas contain phyllosilicate-rich layers
Glowing terrain	-	-	Detection of chloride	-	Polygonal fracturing, lack of sulfates
Siliceous layered deposits	-	-	-	High-Si deposits at Home Plate	Widespread hydrated silica in layered deposits on Hesperian plains

2004

The growth in information in the last 3 years shows that **<u>we are still in an active phase of discovery</u>**

Summary of Deposit Types (1-2)

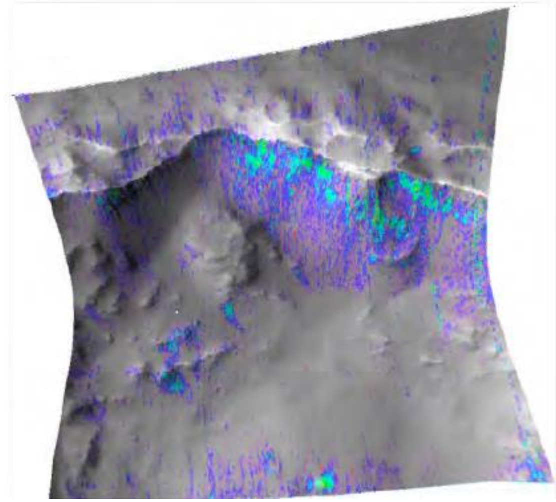
Noachian layered clays (type: Mawrth Vallis)

Composition

- Fe/Mg-, Al-rich clays in layers

Morphology

- Exhumed where protective cap rock has been eroded
- Light- and darker-toned layered deposits
- Extensive polygonal fracturing exposed in some locations



Deep Noachian phyllosilicates exposed in highland craters, chasma walls (type: Tyrrhena Terra)

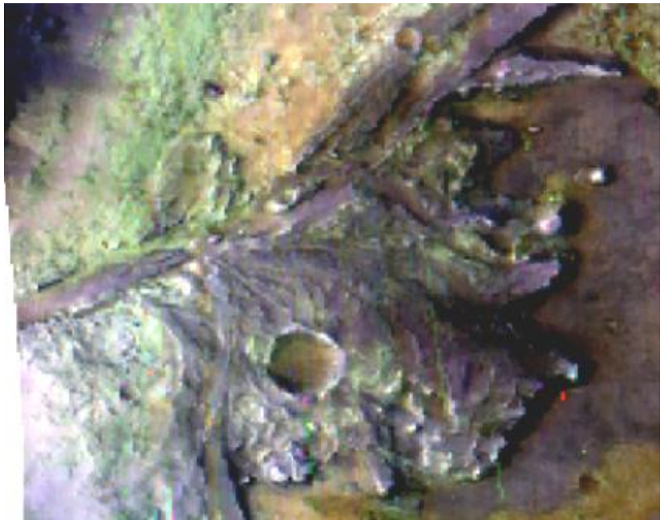
Compositions

- Wide variety of phyllosilicates
- Chlorite is particularly common in highland craters

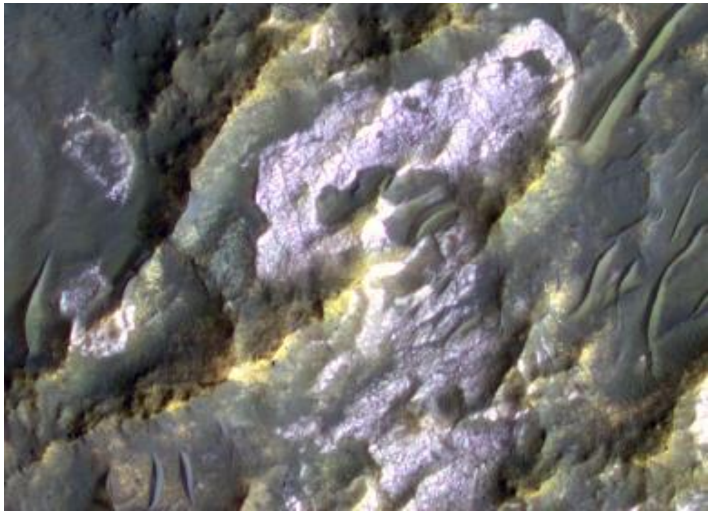
Morphology

- Massive or layered
- Clear evidence for megabreccia in some highland crater central peaks

Summary of Deposit Types (3-4)



Noachian intra-crater fans with phyllosilicate-rich layers (type: Jezero Crater)



Noachian "glowing terrain" (type: Terra Sirenum)

Compositions

- Representative of mineralogy of drainage basin

Morphology

- Typically lower beds are layered and show strongest evidence of phyllosilicate
- Typically overlain by alluvial deposits

Composition

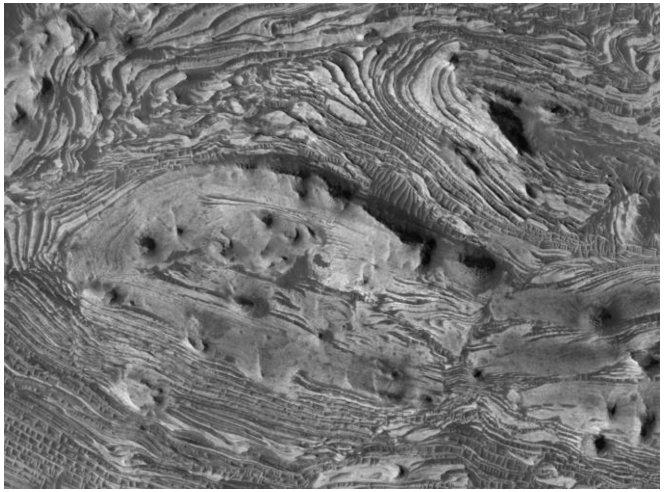
- "Blue" spectrum of apparent emissivity consistent with few geologic materials
- Chloride is the best candidate

Morphology

- Closed basins or topographic lows
- Light-toned and polygonally fractured
- Often occurs as exhumed layers

Summary of Deposit Types (5-6)

Noachian Meridiani-type layered deposits
(type: Terra Meridiani)



Hesperian Valles-type layered deposits
(type: Candor Chasma)

Compositions
- Discrete layers enriched in hydrated sulfates and/or gray hematite

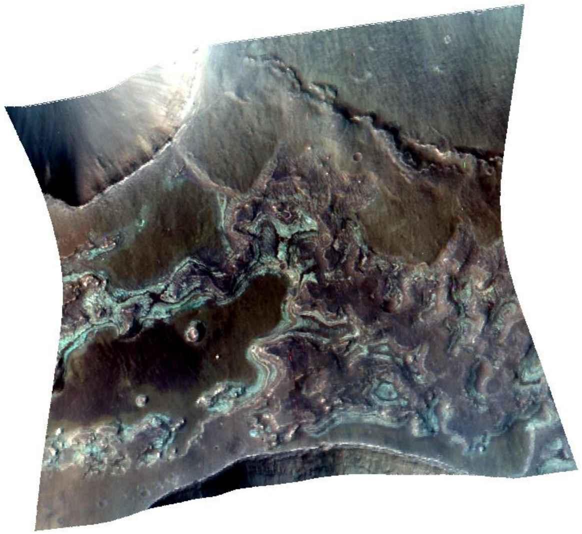
Morphology
- Horizontal, nearly undeformed layers
- Extensive eolian erosion

Only widespread aqueous deposit investigated *in situ*

Composition
- Different sulfates occur in layers
- Associated with gray and red hematite

Morphology
- More and less erosion-resistant layers
- Folding suggests ductile deformation
- Alteration along fracture zones suggests fluid flow through fractures

Summary of Deposit Types (7-8)



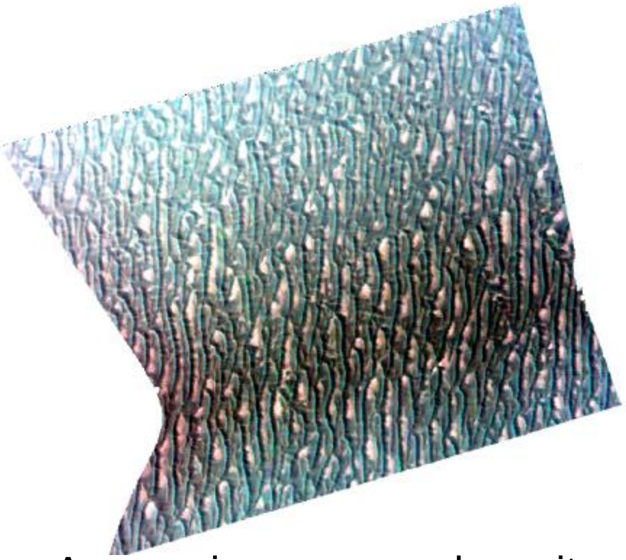
Thin Hesperian layered deposits with hydrated silica (type: Ophir Planum)

Composition

- IR spectra indicate hydrated silica (opal)
- Close spatial association with jarosite

Morphology

- Light-toned layered deposits on Hesperian plains
- Eroded into yardangs
- Some inverted channels



Amazonian gypsum deposits (type: Olympia Undae)

Composition

- Strong spectral signature of gypsum

Morphology

- Strongest gypsum signature in dune crests suggests eolian redistribution
- Polygonally fractured light materials and dark sands analogous to N polar basal unit

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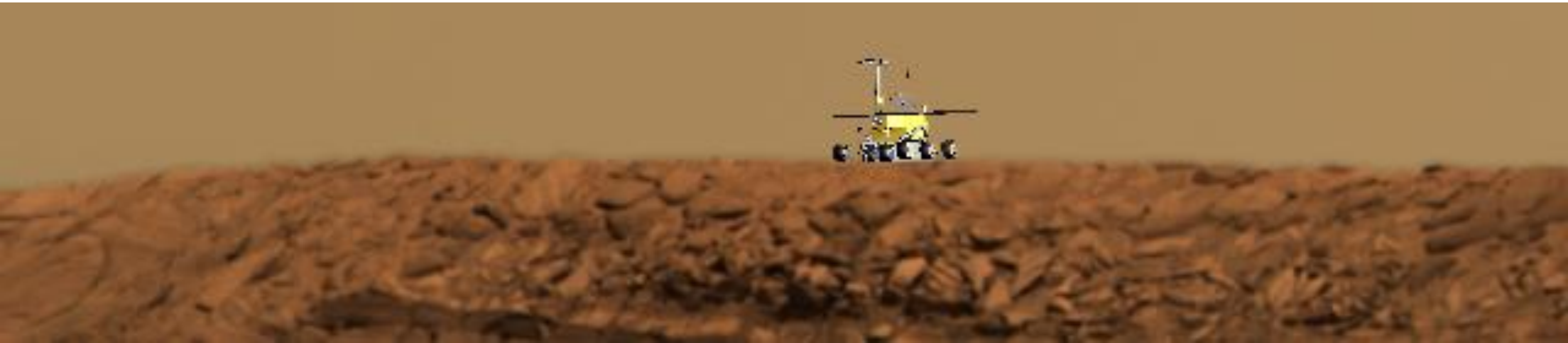
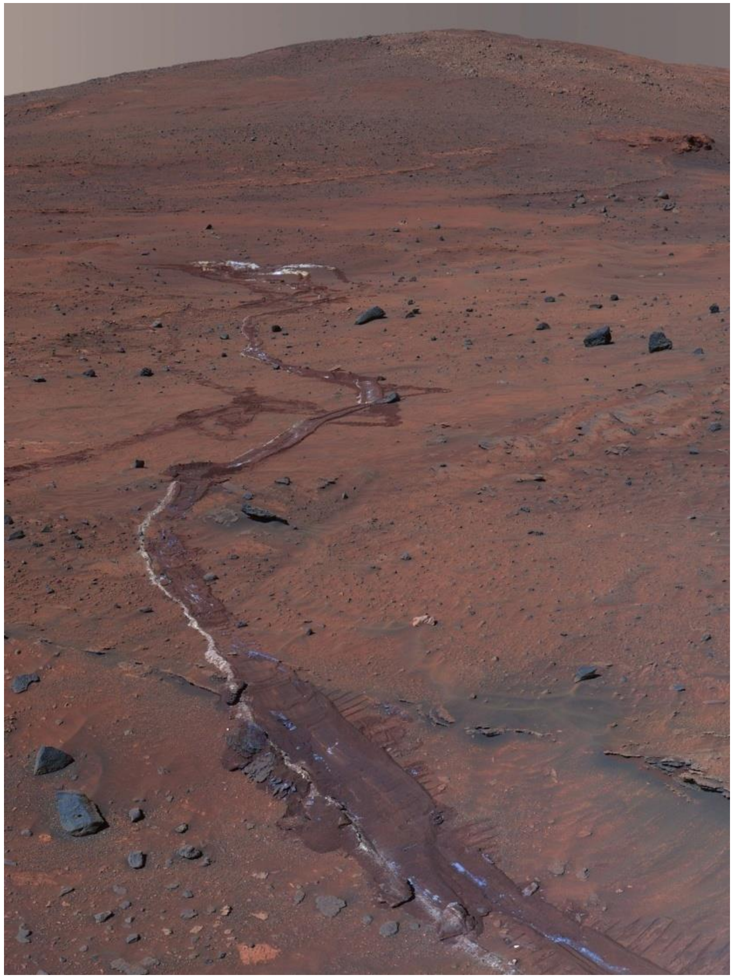
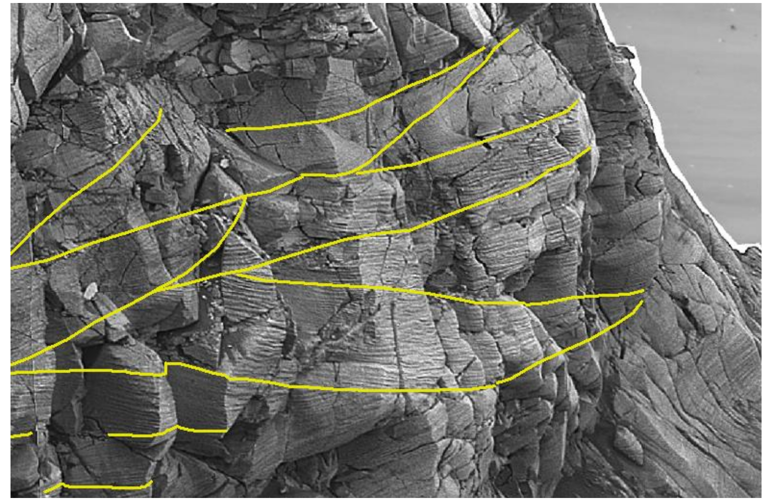
Lessons from MER

- **Opportunity investigated the first orbital detection of a possible aqueous mineral - gray hematite**
- **Possible genetic mechanisms (from original TES discovery)**
  - Sedimentation from surface waters.
  - Precipitation from hydrothermal fluids
  - Alteration of basalts
- ***In situ* measurements were essential to interpreting origin**
  - None of the original hypotheses was correct
  - #1 was closest (diagenesis of eolian sediments by groundwater, deposition and reworking by surface waters)
- **6 technical capabilities proved essential**



Lessons from MER



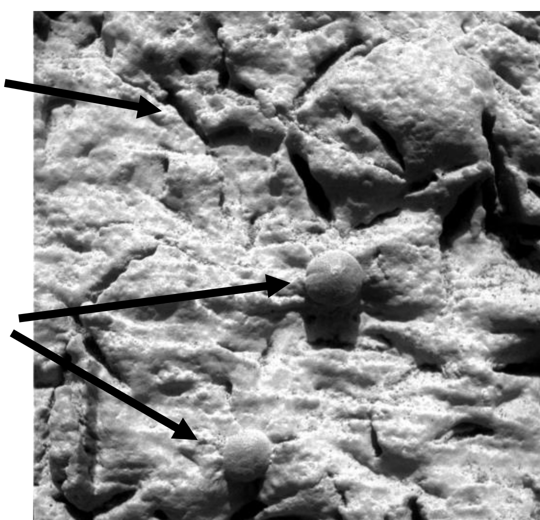


Panoramic imaging with sufficient resolution:
- detects geologic units
- characterizes structures

Microscopic imaging reveals textures needed to understand lithologies

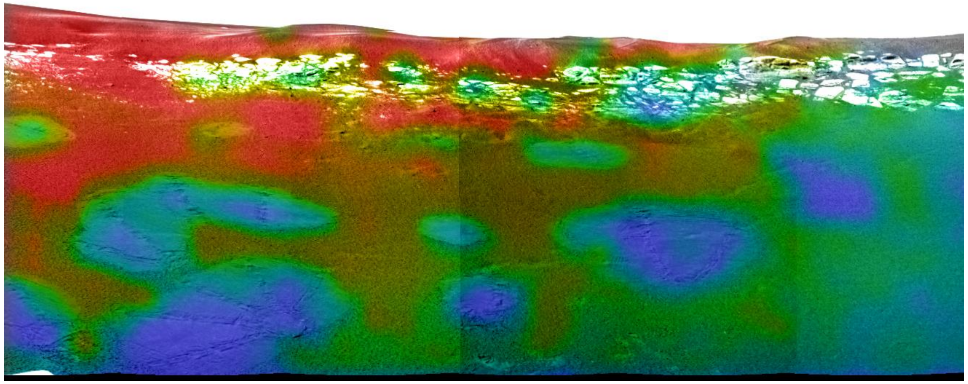
Gypsum Crystal Mold

Spherules



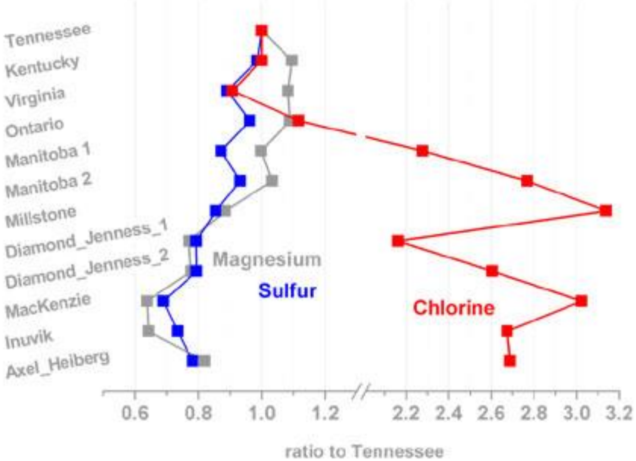
Accessibility (precision landing + mobility) is critical to reach deposits of interest. Crossing a contact during an extended mission is like landing at two sites.

Lessons from MER



Spectral mapping shows mineral distribution and relates it to imaging results, to identify key sites for contact measurements

An abrasion tool provides fresh surfaces for accurate elemental composition measurements



Elemental composition measurements show geochemical trends needed to understand depositional and alteration environments

Lessons from Site Characterization

- **The Phoenix and MSL landing site selection processes provide previews for potential site selection for MSR**
- **Sub-meter resolution HiRISE images are essential to characterizing site geology and certifying safety**
- **CRISM and THEMIS images are essential to screen sites for preserved aqueous mineralogy**

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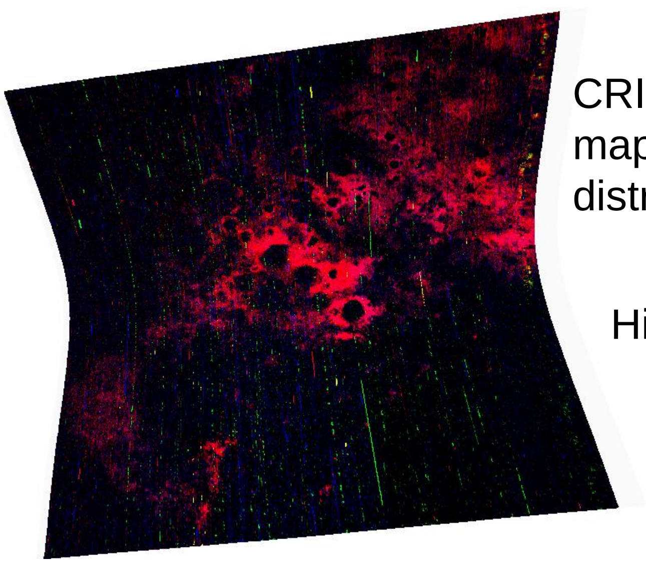
TIFF (LZW) decompressor
are needed to see this picture.



CRISM mineral indicator map of phyllosilicate distribution

HiRISE image showing boulders and slopes

MEPAG Evaluation of Missions / Complementary Science

Assumptions

- An aeronomy Scout would launch in 2013, and carry a telecommunications package
- MSR would select, characterize, and collect samples as per ND-SAG recommendations and would not be restricted to retrieval of an MSL or ExoMars cache
- For a proposed 2016 a flagship-class mission is fiscally untenable

Proposed mission candidates

- Network: 4 landed stations with MET packages, heat flow and seismic investigations
- MSO: climatological and trace-gas investigations outlined by MSO SDT
- Mid-Rover: MER-like rover with updated instruments, comparable mobility and lifetime, 6-km landing ellipse

Evaluation criteria

- Qualitative scoring of potential returns against MEPAG goals and objectives, especially in context of complementing MSL and MSR
- Pro's and con's of each option

Option: Network

❑ PRO:

- Seismic grid addresses high-priority objectives related to Mars' interior
  - Structure of the shallow interior provides a boundary condition for subsurface habitable zones
  - Structure of the deep interior provides insight into history of the magnetic field, an important constraint on history of the atmosphere
  - Highest priority after sample return in NRC reports / Decadal Survey
  - With sample return, both major NRC objectives would be achieved
- Could easily be part of an international collaboration

❑ CON:

- No precursor science to MSR
- Science is less complementary to MSR than other cases

❑ Note

- Science feasibility of heat flow measurements, coupling of seismic device to surface may require a precursor demonstration (e.g. on ExoMars) with time to feed forward lessons learned to a Network

Option: MSO Baseline Atmospheric Science

- **PRO:**
  - Investigation of trace gases addresses present-day habitability
    - Could identify “new” special regions having subsurface activity
    - Could lead to paradigm-altering findings
  - Complements MSL, MSR focus on past habitable environments
  - Continues the baseline of climatological measurements
  - Synergistic science (lower atmosphere) with aeronomy Scout (upper atmosphere)
- **CON:**
  - Science feed-forward to MSR is less tangible than for rover

Option: Mid-range Rover

- **PRO:**
  - Characterization of a new site follows up on discovery of diverse aqueous deposits
  - Investigation of each type of deposit promises significant new insights into the history of water on Mars
  - Provides additional context for proposed MSR samples

- **CON (for a 2016 launch):**
  - Combination with MSR could address a lesser range of objectives than does MSO
  - Depending on longevity of MRO and Scout, proposed launch in 2016 instead of MSO could introduce a gap in assessment of interannual atmospheric variability

Finding: Framework for Future Missions

- **The "follow the water" theme of Mars exploration has been coming to fruition in the last 3-4 years. Two obvious reasons are:**
  - Adherence to a stable set of goals
  - New missions build on results of older ones in a well thought-out fashion
- **This is consistent with the report of NRC Committee on Assessing the Solar System Exploration Program:**
  - "NASA's Mars Exploration Program (MEP), which was redesigned in 2000, has been highly successful to date and appears on track through the end of the current decade. Both the Mars Science Laboratory (in 2009) and a 2011 Scout mission that will be selected soon meet the recommendations of the decadal survey. <u>A key element of the success of this program is that it is not a series of isolated missions, but rather a highly integrated set of strategically designed missions, each building on the discoveries and technology of the previous missions and fitting into long-term goals to understand the planet</u>, whether or not it ever had or does now have life, and how Mars fits into the origin and evolution of terrestrial planets.".....
- **A continued stable, planned program will be critical to future science return**

Finding: Direction for Future Missions

- The MEP has "followed the water" to a diversity of water-related features and surface deposits.
- There are unanswered questions about each class of deposit, that MER showed can be addressed with *in situ* measurements:
  - Sedimentary textures
  - Grain- to outcrop-scale mineralogy
  - Elemental abundances and gradients
- There are also unanswered questions about present habitability, especially whether trace gases are a signature of present habitable environements
- The focus on future missions should be "exploring habitable environments" of the past and present. Key measurements are:
  - Sedimentary textures, grain- to outcrop-scale mineralogy, and elemental abundances and gradients in different classes of aqueous deposits
  - Abundances and spatial/temporal variations of trace gases and isotopes in the present atmosphere

Finding: Early Sample Return

- **The most comprehensive measurements of water-formed deposits would be made on returned samples**
- **The highest science priority future mission to "explore habitable environments" would be sample return with an MSR Lander/Rover which would be launched to Mars no later than 2020.**
  - The science return would be enormous, and cross-cut MEP goals
  - All other recommendations follow from this.

Findings: Support for Sample Return

- **MSR, ExoMars, and future landed mission could systematically sample known diversity on the surface. Site selection and certification could be carried out using Mars Express, Odyssey, and MRO data, PROVIDED there are adequate observations, data analysis, and mission lifetime.**
  - MRO and Odyssey should be utilized to characterize hundreds of sites and to certify sites for sample return.
  - A group of engineers and scientists should be formed, and investigators funded, to:
    - Analyze already-acquired data
    - Guide acquisition of new data by missions in their extended phase(s)
  - Otherwise, it would be necessary to fly at least a HiRISE-class imager for site certification.
    - Such an imager should be launched two opportunities earlier than the proposed MSR Lander/Rover (i.e., no later than 2016), to ensure adequate time for the data acquisition and analysis needed to certify the site.
    - MSO could carry this imager in 2016; an MSR orbiter in 2016 probably could not, due to unfavorable energetics of the launch opportunity

Findings: Augmented MSR Science

- ❑ **The MSR orbiter and lander/rover could provide opportunities for complementary science, provided sample return would not be jeopardized:**
- ❑ **If the MSR rover would still be functional after samples are returned to the Lander/MAV, operations should be extended in order to:**
  - measure new outcrops
  - if possible investigate an additional geologic unit.

Findings: Pre-MSR Missions

2011	skip	
2013	Aeronomy Scout	ExoMars
2016	MSO	

❑ **The SAG reached consensus regarding:**
- recommendations for missions in addition to MSR, Mars Scout
- insight over the 2020 horizon

❑ **MSO trace gas and climatologic investigations should come first because**
- They would focus on present habitable environments, while MSL and MSR would focus on past environments. This would be a balanced investigation of habitability.
- Results would have potential for a large impact on our understanding of Mars an on future missions
- They would provide continuity in the climate baseline
- They would be synergistic with Mars Scout

❑ **Site certification capabilities would not be required, if MRO is adequately utilized and has sufficient life**

❑ **A mid-rover was a close second priority because it could investigate an additional past habitable environment**

Findings: MSR Sequence

2011	skip
2013	Aeronomy Scout / ExoMars
2016	MSO
2018	MSR-Lander/Rover
2020	MSR-Orbiter

- **A 2016 launch for MSR-Orbiter would be unfavorable energetically and may preclude complementary science**
- **A 2022 launch for MSR-Lander/Rover would be unfavorable energetically**
- **The 2018 and 2020 opportunities for MSR could maximize their science potential**
- **2013/2016 telecom capabilities could provide an extended rover mission after the MAV is launched**

Findings: Post-MSR Sequence

2011	skip	
2013	Aeronomy Scout	ExoMars
2016	MSO	
2018	MSR-Lander/Rover	
2020	MSR-Orbiter	
2022	Network	
2024	Mid range rover	
2026	Scout	
2028	MSR-Orbiter 2	
2030	MSR-Lander/Rover 2	

- **Network is highly recommended by the NRC and would complement MSO and MSR with strength in additional high-priority objectives**
- **A mid-range rover could investigate an additional class of aqueous deposits while implications of MSR science being discovered**
- **New findings from Scout, ExoMars, MSO, MSR-Lander would support innovative, community-driven science**
- **After operations and first analyses of returned samples yield lessons learned, a second sample return would yield new and complementary results**

Summary

- The MEP is on the cusp of major revelations about Mars' past and present habitability, and whether life ever existed on Mars
- A well-planned program got us here
- The next steps are exploring past and present habitable environments
- Continued measurements with existing assets will prepare for future landed missions to investigate past habitable environments
- MSR would be the most important of the landed missions, but understanding the diversity of past wet environments would take several more landed missions
- Prior to MSR, an MSO mission would focus on trace gas and climatologic investigations would provide highly complementary (and perhaps paradigm-altering) results on present habitability

BACKUP

MEPAG Qualitative Comparison of Proposed Candidates

Priority	#	Investigation	2010 MSL	2013-2016 MSO (atmospheric)	2013-2016 Network	2013-2016 Mid-range Rover	2018-2020 MSR (assuming non-polar site)
HIGH	1	CURRENT DISTRIBUTION OF WATER					
	2	GEOLOGIC H2O HISTORY					
	3	C,H,O,N,P, AND S - PHASES					
LOW	4	POTENTIAL ENERGY SOURCES					
HIGH	1	ORGANIC CARBON					
	2	INORGANIC CARBON					
	3	LINKS BETWEEN C AND H, O, N, P, S					
LOW	4	REDUCED COMPOUNDS ON NEAR SURFACE					
HIGH	1	COMPLEX ORGANICS					
	2	CHEMICAL AND/OR ISOTOPIC SIGNATURES					
	3	MINEROLOGICAL SIGNATURES					
LOW	4	CHEMICAL VARIATIONS REQUIRING LIFE					
HIGH	1	WATER, CO2, AND DUST PROCESSES					
	2	SEARCH FOR MICROCLIMATES					
LOW	3	PHOTOCHEMICAL SPECIES					
HIGH	1	ISOTOPIC, NOBLE & TRACE GAS COMP.					
	2	RATES OF ESCAPE OF KEY SPECIES					
	3	ISOTOPIC, NOBLE, AND TRACE GAS EVOLUTION					
	4	PHYS AND CHEM RECORDS					
LOW	5	STRATIGRAPHIC RECORD--PLD					
HIGH	1	THERMAL & DYNAMICAL BEHAVIOR OF PBL					
	2	ATM. BEHAVIOR 0-80 KM					
	3	ATM. MD 80-200 KM					
LOW	4	ATM. MD >200 KM					

LEGEND	
Major contribution	
Significant contribution	
2013-2016 investigations not addressed by MSR lander	

Strong contribution to high-priority Goal II objectives would not be addressed by MSR; extends local MSL results spatially

MEPAG Qualitative Comparison of Proposed Candidates

			2010	2013-2016			2018-2020
		Investigation	MSL	MSO (atmospheric)	Network	Mid-range Rover	MSR (assuming non-polar site)
HIGH	1	**PRESENT STATE AND CYCLING OF WATER**					Significant
	2	**SEDIMENTARY PROCESSES AND EVOLUTION**	Significant			Major	Major
	3	**CALIBRATE CRATERING**					Major
	4	**IGNEOUS PROCESSES AND EVOLUTION**	Major		Significant	Significant	Major
	5	**SURFACE-ATM INTERACTIONS**	Significant			Significant	Major
	6	**LARGE-SCALE CRUSTAL VERT STRUCTURE**	Significant		Significant	Significant	Significant
	7	**TECTONIC HISTORY OF CRUST**		Not addressed by MSR	Major; not addressed by MSR	Not addressed by MSR	
	8	**HYDROTHERMAL PROCESSES**	Major		Significant		Major
	9	**REGOLITH FORMATION AND MODIFICATION**	Significant		Significant	Significant	Significant
	10	**CRUSTAL MAGNETIZATION**					Significant
LOW	11	**EFFECTS OF IMPACTS**	Significant		Significant	Significant	Significant
HIGH	1	**STRUCTURE AND DYNAMICS OF INTERIOR**			Major		Significant
	2	**ORIGIN AND HISTORY OF MAGNETIC FIELD**			Major		Significant
	3	**CHEMICAL AND THERMAL EVOLUTION**	Significant		Significant	Significant	Significant
LOW	4	**PHOBOS/DEIMOS**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
HIGH	1	**DUST - ENGINEERING EFFECTS**	Significant			Significant	Major
	2	**ATMOSPHERE (EDL/TAO)**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	3	**BIOHAZARDS**	Significant				Major
	4	**ISRU WATER**					Significant
	5	**DUST TOXICITY**					Major
	6	**ATMOSPHERIC ELECTRICITY**		Not addressed by MSR	Significant; not addressed by MSR	Not addressed by MSR	
	7	**FORWARD PLANETARY PROTECTION**					Significant
	8	**RADIATION**	Significant	Not addressed by MSR	Significant; not addressed by MSR	Not addressed by MSR	
	9	**SURFACE TRAFFICABILITY**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	10	**DUST STORM METEOROLOGY**		Not addressed by MSR	Significant; not addressed by MSR	Not addressed by MSR	
	1	**AEROCAPTURE**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	2	**ISRU DEMOS**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	3	**PINPOINT LANDING**		Not addressed by MSR	Not addressed by MSR	Significant; not addressed by MSR	
	4	**TELECOM INFRASTRUCTURE**		Major; not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
	5	**MATERIALS DEGRADATION**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	
LOW	6	**APPROACH NAVIGATION**		Not addressed by MSR	Not addressed by MSR	Not addressed by MSR	

LEGEND	
Major contribution	Major
Significant contribution	Significant
2013-2016 investigations not addressed by MSR lander	Not addressed by MSR

Would address interior questions in ways not possible with MSR, MSL

Qualitative Comparison of Proposed Candidates

			2010	2013-2016			2018-2020
		Investigation	MSL	MSO (atmospheric)	Network	Mid-range Rover	MSR (assuming non-polar site)
HIGH	1	PRESENT STATE AND CYCLING OF WATER					
	2	SEDIMENTARY PROCESSES AND EVOLUTION					
	3	CALIBRATE CRATERING					
	4	IGNEOUS PROCESSES AND EVOLUTION					
	5	SURFACE-ATM INTERACTIONS					
	6	LARGE-SCALE CRUSTAL VERT STRUCTURE					
	7	TECTONIC HISTORY OF CRUST					
	8	HYDROTHERMAL PROCESSES					
	9	REGOLITH FORMATION AND MODIFICATION					
	10	CRUSTAL MAGNETIZATION					
LOW	11	EFFECTS OF IMPACTS					
HIGH	1	STRUCTURE AND DYNAMICS OF INTERIOR					
	2	ORIGIN AND HISTORY OF MAGNETIC FIELD					
	3	CHEMICAL AND THERMAL EVOLUTION					
LOW	4	PHOBOS/DEIMOS					
HIGH	1	DUST - ENGINEERING EFFECTS					
	2	ATMOSPHERE (EDL/TAO)					
	3	BIOHAZARDS					
	4	ISRU WATER					
	5	DUST TOXICITY					
	6	ATMOSPHERIC ELECTRICITY					
	7	FORWARD PLANETARY PROTECTION					
	8	RADIATION					
	9	SURFACE TRAFFICABILITY					
	10	DUST STORM METEOROLOGY					
	1	AEROCAPTURE					
	2	ISRU DEMOS					
	3	PINPOINT LANDING					
	4	TELECOM INFRASTRUCTURE					
	5	MATERIALS DEGRADATION					
LOW	6	APPROACH NAVIGATION					

LEGEND
Major contribution
Significant contribution
2013-2016 investigations not addressed by MSR lander

Potential to extend analytical capabilities to classes of deposits not measured by MSL or MSR

Mars in New Frontiers

- **The Network and Mid-range Rover missions would both address high-priority science at fit the cost profile of a New Frontiers mission**
  - First seismic measurements for a planet outside the Earth-Moon system
  - *In situ* investigation of a possibly habitable site of past water
- **However both missions could have greater science impact as part of a planned sequence**